Proceedings of the International Conference on Aerospace Science and Technology
26 - 28 June 2008, Bangalore, India

INCAST 2008- 099

AVIONICS FLIGHT TESTING OF LIGHT TRANSPORT AIRCRAFT-MODERN TRENDS AND CHALLENGES

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ABSTRACT: Flight Testing is an important phase of any aircraft development program, which deals with pre and post flight test activities for successful certification of aircraft. This involves flight planning, flight-testing, flight data analysis and validation as part of the data analysis process. The data, so acquired during the flight test is used to evaluate the flight performance of aircraft and its sub–systems in terms of their design objectives complying with design, development and testing standards.

The primary objectives of flight-testing are to find the transparent or hidden design problem and to fix them as part of the process. Also the document verification with regard to the compliance to the relevant standards based on aircraft category along with aircraft system functionality requirements.

SARAS, 14 seater twin turbo-prop multi-role aircraft is being flight-tested with two prototype aircrafts flying in parallel to accomplish the flight-testing for system and sub-system functionality. This paper describes the flight test activities of SARAS in general and avionics functionality in particular. Flight trials can be divided into 3 sections, planning, execution and analysis and reporting. These sections and process involves meticulous planning, methodical approach towards appropriation of test functionality for each sortie, efficient data capturing, effective data analysis, intelligent problem definition and result conclusion.

This paper covers the appropriate relevant flight test sections applicable to SARAS in accordance with the FAA Advisory Circular 25-7A. The avionics subsystems of SARAS are broadly classified as Communication System, Navigation System, Warning System, Radar System, Display System, and Recording System. Also details the process, procedure, methodology, activities, standards and approach towards avionics flight-testing. Flight Testing is highly expensive and potentially very risky. Unforeseen problems can lead to damage to aircraft and loss of life, both of aircrew and people on the ground. For these reasons modern flight-testing is probably one of the most safety conscious professions today. Hence sufficient safety procedures and pro-active precautions followed during the flight test planning, execution and analysis and reporting is addressed with practical scenarios and case studies. The flight test system architecture is also addressed in brief as part of the complete setup. An effort is made to bring out the practical, procedural, safety and functional problems faced during the flight-testing of SARAS.
Keywords: DAU, GPU, HSI, CAS, DME, VOR/ILS, ADF, RTU, RMI, PVI

1. INTRODUCTION: SARAS is a twin turbo-prop, multi role aircraft, with air taxi and commuter services as its primary roles. SARAS aircraft requires airworthiness and operational certificate from Directorate General of Civil Aviation (DGCA) to fly in the Indian sky and FAA certificate to fly globally. Airworthiness certificate ensures that the aircraft and its systems meet the intended performance and safety requirements. SARAS is being flight-tested and completed 142 flight hours covering primarily the handling qualities and power plant testing in particular to climb performance.

The primary goal of the flight-testing is to gather accurate flight performance data and then analyze the data to evaluate the flight characteristics of the aircraft and validate its design including safety aspects. The flight test phase accomplishes two major tasks. One is identifying and fixing design problems and then next verification and documentation for certification or customer acceptance.The flight test phase can range from the test of a single new system for an existing aircraft to the complete development and certification of a new aircraft. Therefore the duration of a flight test program can vary from a few weeks to several months [2].

1.1 Aircraft Telemetry System: Flight test programs of SARAS use PCM based Data acquisition Unit(DAU). Telemetry is summarized under three headings: Instantaneous monitoring, Safe conduct of trials and Optimum use of flying time [3]. Telemetry can give immediate information on the ground of what is going on in an aircraft.

On board data acquisition is carried out using DAU.The data acquistion systems have been interconnected in a distributed architecture to form a master and slave configuration. The data from all avionics LRU's acquired by the master unit and all sensors outputs from the engine, wing and other parts are brought to the slave which are controlled by the master unit for data acquistion. The master will receive the signals from the slave unit and generate a PCM streams .One stream of PCM data from the master unit encoder module is recorded on SSR and the other PCM stream is fed to an L-band FM Telemetry transmitter. The transmitter, centered at 1500MHz, with a power output of 20 W feeds two antennas on the aircraft. The ground station will receive the modulated PCM data and demodulated using decommutator and decoded by the bit synchronizer. The real time data is converted into engineering units and displayed on several monitors from the server system. The schematic block diagram is shown in figure 1. For SARAS PT-1, data acquisition rate is 16Hz, this sampling rate is configurable depending on requirements of critical data.

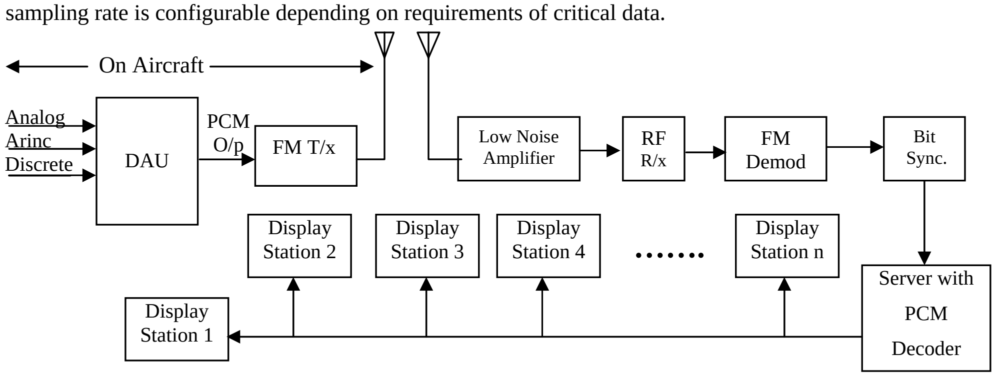

Figure 1: Block Diagram of typical Telemetry system for flight test activity

2. FLIGHT TEST PROCESSES:

2.1 Pre-flight Test activities: The flight test plan document gives a systematic approach to the effective, efficient, and safe conduct of the test program. The schedule given by various flight test groups is incorporated into a flight test plan which defines the purpose of the test, the scope of the test, the test methods used; the risks involved with the test. The preflight test activities are mandatory before each flight. All related and feasible flight test scenarios are combined into a single flight test plan and the data is collected on the same sortie enabling reduced number of flights to achieve the flight test objectives for requried test points.The flight test instrumentaiton system can be configured for various datasets based on flight phase data analysis requriements and hence the parameter datasets used across flight tests depends on the requirements which are derived based on flight test plan and scenarios.

2.2 Briefing: The flight plan cannot be finalized until the prevailing meteorological Information is known. At this time it is a good idea to check with briefing on the level we are likely to be granted; this may be altered subsequently but it will save lot of re-calculation if we plan on a level near to the one we are likely to be granted. Once the flight is planned and the program is ready, the flight test engineer along with the test pilots and the flight test teams briefs about the status of the flight and the execution of the different test points of flight test plan. A sample flight briefing board is as shown in Table 1.

Table 1

SARAS BRIEFING BOARD	
AIM : Control Assessment, Avionics functionality checks	TP1: Climb,120kt,clean 40% T, 6500'-9000'
	TP2: Beta offset check, 120kt clear
AC No : VT-XRM	TP3: Rudder trim tab eff., 120kt,clear(ΔT~25%)
FLT No: 20	TP4: Roll trim tab eff.,120kt, (ΔT ~35%)
AUW : 6080 Kg.	TP5: Repeat TP4 for RH
CREW : W/C Shah/ W/C KP/ S/L Elaya	TP6: VHF checks at 9000'
FUEL : 670 Kg (At takeoff <600 Kg)	TP7: Speed Correction EFIS Vs ISIS (level flt)
R/T : SOP	TP8: VOR functionality Check
Weather: As per Bfg.	Rejoin: ILS check
Start up: SOP(RH Eng → LH Eng)	CCT,App&LDG : δF=0, Vttg >115 kt
Taxi :SOP	Limitations: Vne =160 Kt, Vfo = 125Kt

2.3 Pre-flight Preparation: The flight inspector carries out a normal external pre-flight inspection of the aircraft. The standard check of the aircraft is carried out as recommended by the manufacturers and the design group; it is normally commenced at the door, moving clockwise round the aircraft until reach the point at which you started. Before starting the Engines the normal internal check with the GPU will be completed, ensuring correct operation of radio, navigational aids and instruments to be used in instrument flight. All radio facilities at the station are checked for operability. The QNH given by ATC is set on all altimeters. The VOR and ILS signal, station coding, the flag and the position of the aircraft are checked on the tuned frequency. The ADF is tuned to the appropriate station, the signals identified and the accuracy of the signals checked by the indications of the RMI. The Distance Measuring Equipment (DME) is automatically selected along with the VOR system and indicates the distance from the DME ground station.

After engine start: While taxiing out the serviceability of the instruments is further checked by the pilot during a turn. There is no need to turn the aircraft specially to do this, a turn of thirty degrees on to a new taxi way or the turn on to the runway will provide sufficient heading change. The pilot checks for the artificial horizon, which should remain level and not change in pitch indication. Turn needle shows correct direction of turn. Ball or slip needle lies the opposite way to the turn needle. Indications of VOR and ADFs all show the same amount of turn [4].

3. SARAS AVIONICS FLIGHT TEST PROCEDURES ACCORDING TO THE AC 25-7A: The flight test was carried out under the following given envelope. Altitude: Up to 10000 ft. VSI: Up to 2000 fpm CAS: Up to 160 knots DME: Up to 40 NM.

Installation of modern avionics on aircraft is intended to perform its function, be adequately protected for failure conditions, be arranged to provide proper pilot visibility and utilization, be protected by circuit breakers preclude failure propagation and minimize distress to the aircraft electrical system and the operation of the system not to adversely affect the simultaneous operation of any other system.

The requirements for demonstrating safe operation normally include induced failures during flight. The requirement for failure demonstration is also an outgrowth of the analysis and laboratory test results and is a result of the particular design being evaluated. In SARAS flight-testing, the failure tests will be conducted in the subsequent flight trials.

3.1 EFIS display system: EFIS is the heart of the cockpit, which interfaces signals from 15 LRUs from different sub systems. EFIS is designed with pilot friendly symbology with digital simplicity assuring precise readings and high reliability. The different flight conditions are displayed as symbols and also it has full range of navigation interface capabilities. The EFIS symbology was tested with varying input conditions as part of normal flying like different pitch and roll attitudes of +15/-15 degrees and +30/-30 degrees respectively (25.1301 Para D-1.2)[1]. The altitude and CAS of the aircraft was displayed during different altitudes and speeds. The Symbol Generator (SG) Source, AHRS (ATT) Source, and Air Data Computer (ADC) Source test was conducted successfully on the aircraft depending on the pilot and copilot selection. While in cruise, the NAV selection and functionality was cycled to all navigation sources like FMS, ADF, VOR/LOC, and by pressing the BP1 and BP2 bezel buttons the respective source arrow indicators were displayed on HSI. These tests were verified with the format words of EFIS recorded in FDR.The FDR data is validated using higher sampled SSR data. The Decision Height, the Radio altitude, VSI indicator, Wind-vector arrow, wind speed indicator, and g-meter display position were also checked during the entire flight envelope. All annunciators were displayed with acceptable brightness at its appropriate positions through out the flight trials.

3.2 Communication System: The VHF, RTU and AMS are part of the communication system. The VHF that is tuned by the RTU is connected through AMS to the pilot's headphones, cockpit speakers and to a CVR unit. Intelligible air-air communication and air-to ground communication with audio strength of 5 was achieved at 10,000ft and up to 40 NM. The cross side functionality was checked, to ensure reliable operation. At an altitude more than 18,000 ft and around 160 NM with >10 deg bank and 360 deg turn on both sides, the signal strength will be checked. (25.1301 Para B-1.1, 1.4,1.5,1.6)[1] Also long range, high angle reception and approach configuration tests will be conducted in the subsequent flight trials in the next phase with ceiling altitude and speed.

3.3 Navigation system: The VOR bearing display was quite satisfactory while flying towards and away from the VOR station. The audio identifier was checked for Bangalore station code. In the landing configuration with localizer course inbound and at a distance of 6NM, the localizer and the glideslope indications with full pointer deflection helped the pilot to navigate safely. The DME audio was checked for its station identification. The DME was checked up to a distance of 40 NM with ground speed and TTG was quite reliable. At an altitude of approximately 2000 feet above the station, and at a distance of 25nm, at the different headings from the runway, at different bank angles and at normal pitch altitudes the localizer and glide slope indications will be tested on both sides for full needle deflection (25.1301 Para C- 2.2,2.3,3.2,3.3)[1]. For the DME test at an altitude of 2000 feet above the DME facility and >10 NM from the facility, the intelligibility of the DME signals will be checked. Also long range, high angle reception and approach configuration tests will also be conducted (25.1301 Para C-6.3, 6.4,6.5)[1].

3.5 FMS: Before every take off, the pilot enters the flight plan in to the FMS. During flight the FMS was selected as the navigation source on the EFIS display on a half compass MAP mode and the ranges selected from 25NM up to 500 NM and verified the VOR stations planned. The compass displayed was swapped for both full compass mode and MAP/ARC mode.

4. POST-FLIGHT TEST ACTIVITIES: After the flight-testing, so called the HOT DE-BRIEF is carried out by all the group members, test director and flight crew to clearly described the tests executed, its observations, results and experiences of the crew. Based on the feedback from the pilots the necessary action will be taken by respective design groups before commencement of the next flight. After the flight-testing, the FDR data from the Solid State Cockpit Voice and Flight Data Recorder (SSCVFDR) is downloaded and processed using NALFOQA**.** It is an in house software program used for the analysis of flight data. The purpose of Flight Operations and Quality Assurance Program (FOQA) is for the enhancement of air safety. In practice, a FOQA program is a subset of a total in-flight data system that includes engine, maintenance and aircrafts-systems monitoring. The SSCVFDR records vital parameter of aircraft for monitoring and analysis of various aircraft systems in order to predict impending problems and get rectification done before it becomes catastrophic failure. The FDR data is of utmost importance for investigation after incidents or accidents.

The processed SSR data is made into separate files such as Avionics, Aerodynamics, Electrical etc. and distributed among the different teams of the flight test group for further analysis. The flight data is plotted in different phases takeoff, landing, cruise and compared with the expected values and also dual instruments in the aircraft are compared with their accuracy and tolerance. This process continues for all the flight parameters. If the results are matched with the expected values continuously for three flights the system performance is good. In case of any mismatch, the design of subsystem is fine tuned in such a way that the probability of uncertainty is minimized. The combination of analysis, laboratory, and flight evaluation will form the whole of the certification requirements, which will be well documented.

4.1 Methodology adopted for snag rectification: These tests methodologies are carried out in multiple stages starting from ground rig test to on aircraft testing. Based on the pilot's feedback and data analysis, functional verification and debugging starts from the ground test rig using various testers like IFR-4000 & 6000 etc and also simulating the error in the simulation program. This provides an accurate and stable means of testing and calibration. The bench test results are compared with flight data, if it matches the bug is fixed on the aircraft with proper clearance or if snag persists the design team handles the problem and processes further action to be taken by contacting the vendor. The snag rectification process is shown in figure 3. A typical ILS plot during landing is shown in figure 4.

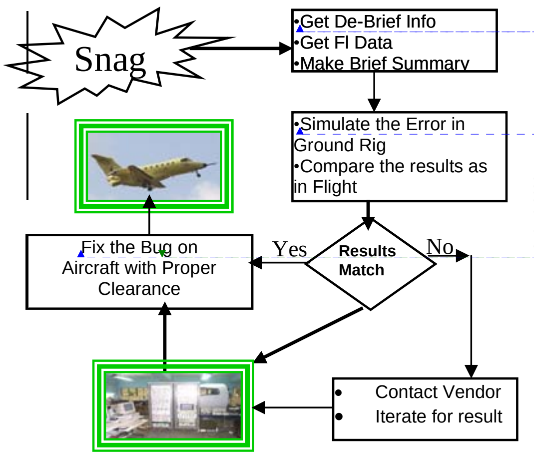

Figure 3: Snag Rectification Process

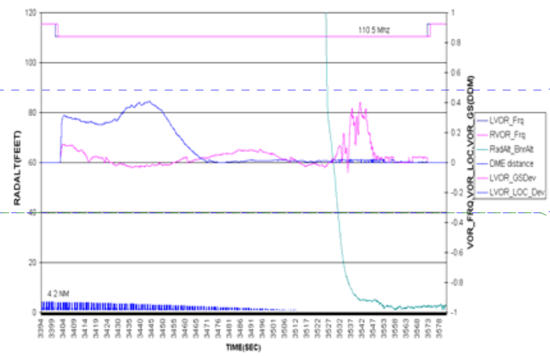

Figure 4: Plot of ILS and Radalt

5. CONCLUSIONS: Avionics flight-testing of SARAS is being carried out effectively using Prototype 1 and 2 defining definite test scenarios and test points for each flight. Primarily the bulk of flight tests so far completed is on power plant and in particular to FAR compliance to climb performance and handling qualities. Sufficient test flights were completed for avionics also covering mainly the cockpit PVI related tests and in particular to display symbology, functional NAV-COM and take-off and landing profile tests. Large SARAS family will be added with one more aircraft called Production Standard Aircraft (PSA) by 2009 and in combination to PT1 and 2. The flight tests of SARAS are expected to complete with PT1, PT2 and PSA together covering approx 500 flight hours. Also the SARAS PT2 will be integrated with Digital Autopilot by end of 2008 after which the Autopilot related tests will be planned.

Avionics flight-testing of SARAS in total is quite satisfactory and the progress is quite good. PSA will be augmented with TCAS, Autopilot and Engine Indication Crew Alerting System (EICAS) also as part of avionics suite, which will enhance the functionality, and hence the flight-tests realted to certification of these systems on board.

6. REFERENCES:

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